ISSN: 2634 - 8845

Journal of Earth and Environmental Science Research

Research Article

Open Access

Assessment of Microplastic Contamination in Surface Water of River Benue in Makurdi Metropolis, Benue State, Nigeria

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ABSTRACT

Microplastic contamination has emerged as a significant environmental concern, with freshwater ecosystems increasingly recognized as critical zones for contamination. This study investigated microplastics contamination in surface water of River Benue in Makurdi, Benue State, Nigeria. Water samples were collected from five locations namely; Brewery, Wadata market, Rice mill Wadata, New bridge and Old bridge as the selected sites of the river Benue within Makurdi metropolis and taken to the laboratory for sample preparation and extraction of microplastics. Microplastic particles were identified with Fourier Transform-Infrared Spectroscopy (FTIR). The findings reveal widespread contamination, with microplastic concentrations varying along the river's course. The abundance of microplastics was found to be 51.32± 0.49 in old bridge (OD), 54.02 ±0.46 in Wadata market (WD), 53.98 ± 0.26 in Rice mill (RM), 39.98 ±0.72 in New bridge (NB), and 49.77± 0.52 in Brewery Site (BW) particles/kg in sediment, and 7.64 ± 0.22 in 3L of water sample in Old bridge(OD), 10.46 ± 0.72 in Wadata market(WD), 7.96 ± 0.22 in Rice mill wadata (RM), 3.92 ± 0.44 in New brigde (NB), and 13.14 ± 0.28 in Brewery site (BW) particles/L in water. The predominant types of microplastics identified primarily composed of polyethylene terephthalate, polypropylene, polyvinyl chloride, polyamide and polyester the most commonly used Polymers. The Benue State government should provide good recycling facilities to help reduce the amount of plastic waste that ends up in river Benue and also monitor the river and its environs to ensure proper waste disposal and management.

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Received: January 18, 2025; **Accepted:** January 21, 2025; **Published:** March 05, 2025

Keywords: Microplastic, Fourier Transform Infrared Spectroscopy (FTIR), Fresh Water, Makurdi, River Benue

Introduction

People hold diverse values towards nature, yet simultaneously, natural ecosystems are undergoing unprecedented degradation and destruction [1]. One method of assessing and communicating nature's value to humanity involves highlighting the essential reliance of humans on nature through the concept of 'ecosystem services' or 'nature's contributions to people' [1]. To improve policy implementation and the efficacy of conservation and restoration efforts, high-level science-policy platforms have been established to provide policy makers with comprehensive and agreed-upon information regarding the magnitude of biodiversity and ecosystem loss, as well as future projections [2].

Freshwater ecosystems face significant threats globally with a 64 % decrease in their area from 1997 to 2011 worldwide and a 50% decline in Europe from 1970 to 2008 [3,4]. They are particularly susceptible to the combined impacts of multiple stressors [2]. Throughout history, freshwater bodies such as lakes, rivers, and wetlands, including floodplains, have played crucial roles, with the goods and services they offer being vital for our survival and well-being [5].

Microplastic pollution within freshwater aquatic environments presents a highly intricate scenario, as it encompasses various environmental components such as ditches, streams, rivers, estuaries, temporary and permanent wetlands, ponds, dams, and lakes. Each of these components exhibits distinct characteristics concerning hydrology, chemistry, flora, fauna, as well as the surrounding watershed and land-use patterns. Additionally, freshwater ecosystems can serve as recipients, reservoirs, and conveyors of plastic pollution [6,7].

Microplastic contamination represents a multifaceted issue in the fresh ecosystem with significant implications for both the environment and public health [8,9]. This environmental challenge exemplifies how pollution originating from land sources can extend widely, infiltrating even remote areas such as pristine mountainous regions, wilderness expanses, the Arctic, and the deepest oceanic trenches [10-12]. Given the visible nature of plastic pollution, it has attracted considerable attention from various stakeholders, including scientists, policymakers, the media, and the public. The level of focus on this issue is unprecedented, possibly surpassing that of any other pollution problem in scientific history [13]. This heightened awareness has led to the emergence of new approaches and comprehensive viewpoints for assessing, researching, and addressing the plastic waste crisis [14-16]. The aim of this research is to determine microplastics in water samples from River Benue within Makurdi metropolis.

Materials and Methods

Study Area

The Benue River originates in the Adamawa mountains of the Central Cameroon and flows Westward for about 1,400 km until it meets the Niger River about 450 km above the delta, near the city of Lokoja, Kogi State, Nigeria. The upper reaches of River

Benue forms narrow valleys and contain falls and rapids. Most of the lower portion however is free from rapids and have extensive flood plains (1,800 Km2) and braided stream channels of different sizes which meander across the flood plain. The flood plain also contains seasonally inundated depressions known as Fadamas or wetlands. These provide importance fishery resources which are exploited after the flood has receded [17]. The new bridge over River Benue at Makurdi is located on the eastern edge of Makurdi which receives discharge and runoff from the Eastern part of North Bank, Wurukum and Gyado-villa areas of Makurdi town [18]. The river Benue enters Makurdi metropolitan area (latitude 7°44`150'N and longitude 8° 31`17.00" E and Latitude 7o 46' 59.99o N. and Longitude 6o 45' 59.99' E.) at its tributary with a minor river the Mu and flows on by dividing the city of Makurdi into (North Bank and South Bank). During the rainy season, the river Benue overflows its banks and inundates the grassy riparian zones. However, during the dry season the water level in the river recedes considerably leaving a silted river bed with clear shallow water. The River within Makurdi metropolis receives effluent principally from Wurukum abattoir, Wadata market and industries of Coca-cola Plc, Brewery Plc and Mikap Nigeria Ltd. The river receives copious amounts of human and industrial pollutants/ debris through small open drainages as it flows through the highly populous area of Makurdi [19].

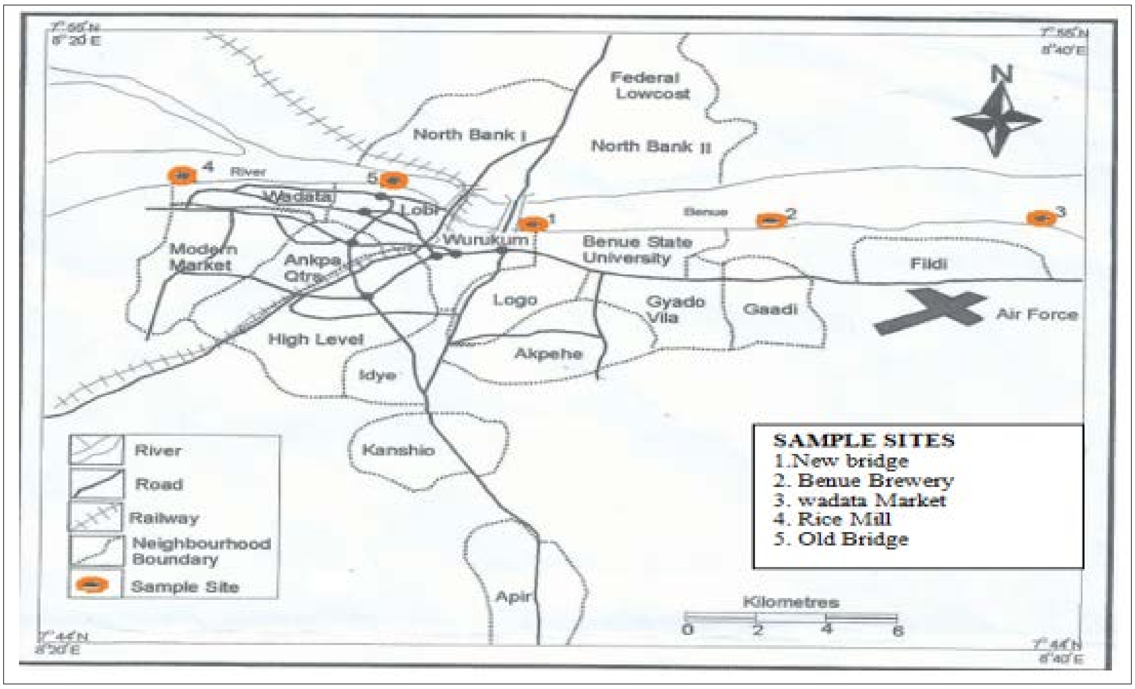

Figure 1: Map of Makurdi Town Showing Sampling sites

Sampling Sites

This research was carried out between April, 2024 to June, 2024 in Makurdi the capital of Benue State. Five sampling sites at approximately 1 Km intervals were mapped along the River Benue within the Makurdi metropolitan area (Figure 1). At each site, water samples were taken.

The sampling sites were as follows:

Brewery Site (BW)

The brewery is located 5 Km away from Makurdi town along Makurdi-Gboko road. The brewery produces effluents from its daily routine production. The effluent is channeled into Ageba, a tributary of River Benue and it flows into the river.

New Bridge Site (NB)

This site was designed II and it's about 5 m from Wadata market. Its effluent flows from the Wurukum abattoir.

Old Bridge Site (OD)

It is about 500 m away from New Bridge and 4.5 Km away from Wadata market. Effluents from New Bridge flow directly into the old bridge Site.

Wadata Rice Mill (RM)

It is about 200 m from Wadata market and about 200m from old bridge. It receives discharge from the Wadata market.

Wadata Market (WD)

Wadata market is located on the bank of River Benue. This site was designed as V and it receives municipal wastes that composed of solid wastes, abattoir effluents and domestic wastes generated from the market.

Collection of Water Samples

At each sampling Site, 3 litres of water samples were. The samples were taken approximately 1 m from the shore with a pre-cleaned jar directly below the water surface and corked immediately and transported to the laboratory for further analysis. The samples were collected against water flow.

Sample Preparation and Extraction of Microplastics

The extraction of microplastics from water samples followed the density separation method [20].

Wet Sieving

Wet sieving was carried out according to the method reported by Masura et al. [20]. Water samples were filtered through a stacked arrangement of 5.6 mm (No. 3.5) and 0.3 mm (No. 50) stainless steel mesh sieves to obtain the microplastics. The mesh was rinsed repeatedly with distilled water to transfer all residual solids to the sieves. The sieves were thoroughly rinsed using distilled water so that no material collected was lost. Materials retained on the 5 mm sieve were discarded while those on the 0.3 mm sieve were collected and dried in the oven at $90^{o}C$ for 24h. Thereafter the mass of the dried solids was determined using analytical balance to the nearest 0.1mg.

Wet Peroxide Oxidation

Exactly 20 mL of aqueous 0.05 M Fe (II) solution was added to the beaker containing the 0.3 mm size fraction of collected, then, 20 mL 30 % H_2O_2 was added and heated at $75^{o}C$. The mixture was kept on the lab bench and allowed to cool at $25^{o}C$ for 5 min followed by the addition of a stir bar to the beaker and cover with a watch glass and heated to $75^{o}C$ on a hotplate. As soon as gas bubbles were observed at the surface, the beaker was removed from the hotplate and paced in the fume cupboard till the boiling subsides. The mixture was again heated at $75^{o}C$ for an additional 30 min. 20mL of 30 % H_2O_2 was repeatedly added until natural organic material was invisible. Thereafter 20 mL of 5M NaCl was added to the sample to increase the density of the aqueous solution. Then the mixture was further heated to $75^{o}C$ for 30 min.

Density Separation

The wet peroxide oxidation solution was transferred to a separatory funnel and covered loosely with aluminum foil to allow solids for 24 h. Visual inspection for settled solids of any microplastics was done and all settled solids were drain from the separator and discarded. The floating solids were collected and examined using FTIR for microplastics contamination.

Characterization with Fourier Transform Infra-Red (FTIR) Spectroscopy

Fourier Transform Infra-Red (FTIR) Spectroscopy analysis of microplastics, using an Agilent T instrument was employed to assess the microplastic contamination along River Benue in Makurdi Metropolis. Micro FTIR analysis is considered one of the most powerful techniques for accurately identifying and diagnosing different types of polymers present in the Microplastics [21]. The polymer types were identified using the transmittance mode Agilent Technologies (Cary 630 FTIR) Infrared microscope (μ-FT-IR). The analysis involved collecting spectra in the 650 to 4000 cm^{-1} range with 16 cumulative scans and a theoretical resolution of 4 cm^{-1}. The PerkinElmer Spectrum Data tune-up program was employed to process the raw spectra, which included default settings such as Beer-Norton strong apodization and automatic baseline correction. The obtained spectra were compared with reference spectral libraries in the Open Specy database (Open Specy.org).

Statistical Analysis of Experimental Data

Microsoft Excel (2010) and Origin 2017 Software were used to compute the experimental data.

Data obtained was analyzed using descriptive statistics:

Results

Concentration of Microplastic in Surface Water at different Sites

The result of microplastic concentration in surface water sampled at different sites in River Benue in Makurdi metropolis is shown in Figure 2. Microplastics were found at all sites in surface water of the River Benue. Microplastic abundance in Old bridge site was found as 7.64 ± 0.22 particle L^{-1}. Microplastic concentration was minimal at Newbridge site (3.92 ± 0.44 particle. L^{-1}) and maximum in Brewery site (13.14 ± 0.28 particle. L^{-1}). The concentration of microplastics in Wadata Market site was (10.46 ± 0.72 particles. L^{-1}) was significantly higher than the concentration found in the Rice mill site (7.96 ± 0.22 particle L^{-1}).

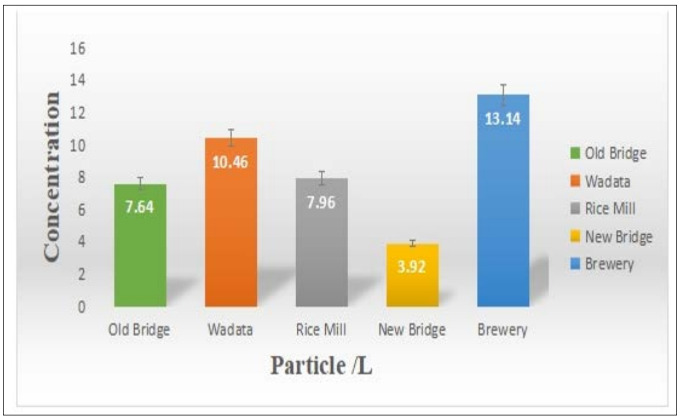

Figure 2: Microplastic Concentration in Surface Water of River Benue around Makurdi Metropolis

Distribution of Microplastics in Surface Water using FTIR

The result of the FTIR of the distribution of microplastics in surface water at different sampling Sites of River Benue in Makurdi metropolis is shown in Figure (3-7).

Brewery Sites for Surface Water

The polymer type identified in the Brewery site of the River Benue freshwater ecosystem in Figure 3 implies that for a wavenumber of 1279.75 cm^{-1}, with a transmittance of 49.64 %, at peak 1, the polymer type can be suggested based on common polymer absorption bands. The wavenumber 1279.75 cm^{-1} falls within a range that is associated with various chemical groups, but it is particularly close to the C-O stretching vibration seen in polymers such as; Polyethylene Terephthalate (PET) often shows peaks in the region around 1250-1300 cm^{-1} due to C-O stretching while Polypropylene (PP) showed peaks near this range, typically between 1250-1300 cm^{-1}, corresponding to C-H bending. Polyvinyl Chloride (PVC) sometimes has peaks around this range, although it is less common.

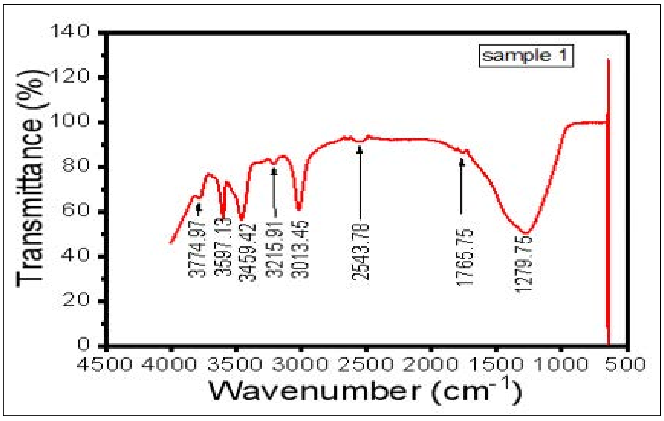

Figure 3: FTIR Spectra of Microplastics in Surface Water at Brewery Site

Old Bridge Site for Surface Water

The polymer type identified in the old bridge site of the River Benue surface water as shown in Figure 4 implies that, for a wavenumber of 1269.17cm^{-1}, with a transmittance of 49.47%, at peak 1, the polymer type is suggested based on common polymer absorption bands. The wavenumber 1296.17 cm^{-1} is within a range that is associated with various chemical groups, but it is particularly close to the C-O stretching vibration seen in polymers like; polyethylene Terephthalate (1250-1300 cm^{-1}) due to C-O stretching of polypropylene (PP) or polyvinyl chloride (PVC).

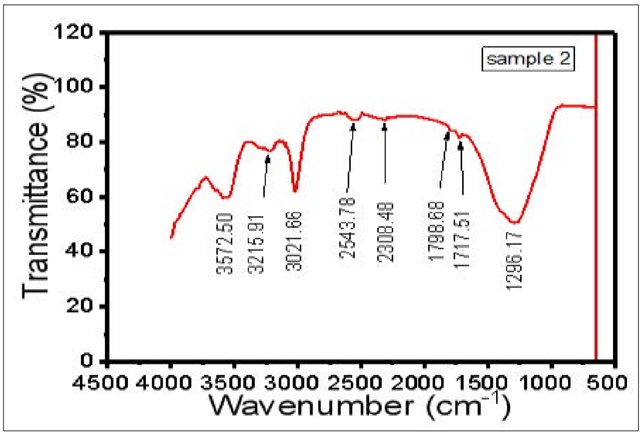

Figure 4: FTIR Spectra of Microplastics in Surface Water at Old Bridge Site

New Bridge Site for Surface Water

The polymer type identified in the new bridge site of the River Benue as seen in Figure 5 implies that, for a wavenumber 1287.96 cm^{-1} and a transmittance of 53.11% can be characteristic of certain functional groups within polymers. At around 1280-1290 cm^{-1}, common polymers like polyethylene (PE), polypropylene (PP), and polyvinyl chloride (PVC) show absorption peaks due to various C-H bending or wagging vibrations: Polypropylene (PP): The wavenumber around 1280-1290 cm^{-1} often corresponds to the CH2 wagging or bending vibrations in PP. Polyethylene (PE): Although PE has similar wavenumbers, the exact match depends on the specific chain configuration. Polyvinyl chloride (PVC): PVC also show peaks in this region due to C-H deformation in the –CH2Cl group. At New bridge Site PP, PE and PVC are the polymer present.

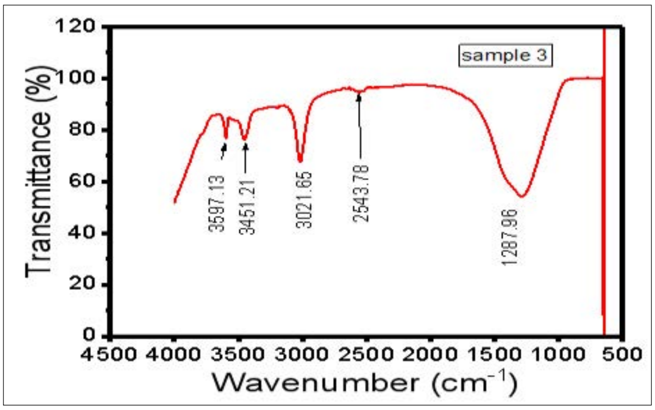

Figure 5: FTIR Spectra of Microplastics in Surface Water at New Bridge Site

Wadata Market Site for Surface Water

The result presented in Figure 6, shows that at around 1270-1280 cm^{-1}, this region typically indicates C-H bending or deformation vibrations which are characteristic of certain polymers: Polypropylene (PP): This region can correspond to C-H bending vibrations in PP. Polyvinyl Chloride (PVC): PVC might also show absorption peaks around this region due to C-H deformation in the – CH_2Cl group. Polyethylene (PE): While PE has peaks in the C-H bending region, they are usually more pronounced slightly higher, around 1290 cm^{-1}. Based on the wavenumber of 1271.55 cm^{-1}, Polypropylene (PP) or Polyvinyl chloride (PVC) are present in Wadata Market Site.

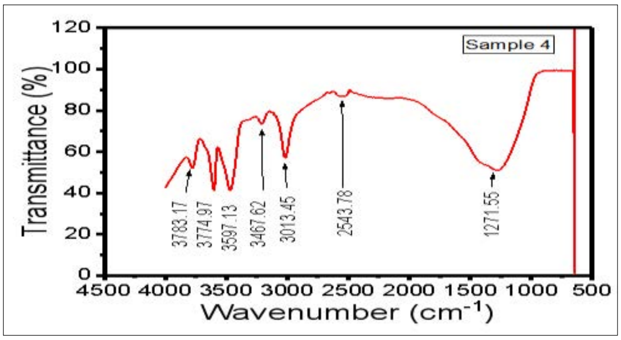

Figure 6: FTIR Spectra of Microplastics in Surface Water at Wadata Market Site

Rice Mill Wadata Site

As presented in Figure 7 below, the wavenumber 1733.92 cm^{-1} with a transmittance of 50.39 % typically corresponds to the carbonyl (C=O) stretching vibration. This wavenumber is commonly found in various polymeric materials. Some of the polymers that exhibit a peak around this region include: Polyethylene terephthalate (PET): Commonly used in plastic bottles and synthetic fibers. Polyvinyl chloride (PVC): The carbonyl stretching could be due to plasticizers or other additives.

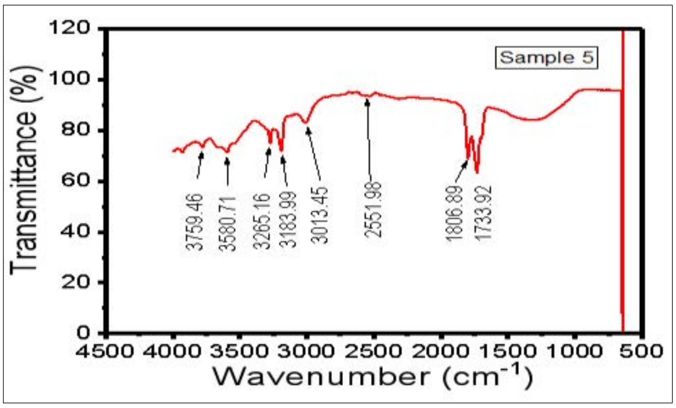

Figure 7: FTIR Spectra of Microplastics in Surface Water at Rice Mill Wadata Site

Table 1: Identified Microplastics in Surface Water of River Benue

Brewery	Wadata Mkt	Rice Mill	New Bridge	Old Bridge
Polyethylene	Polypropylene (PP)	Polyethylene	Polyethylene	Polyethylene
Terephthalate (PET)	Polyvinyl	Terephthalate (PET)	Terephthalate (PET)	Terephthalate (PET)
Polypropylene (PP)	Chloride (PVC)	Polyvinyl chloride (PVC)	Polyvinyl Chloride (PVC)	Polypropylene (PP)
Polyvinyl Chloride (PVC)	Polyethylene (PE)			Polyvinyl Chloride (PVC)

Discussion

Microplastic particles from river Benue Makurdi were analysed by µ-FTIR, which has been a widely used technique in identifying microplastic polymers due to it high reliability in determining chemical compositions of unknown plastic fragments. In this report, the samples were screened for the presence of microplastic particle. The result indicated that microplastic particles were recorded due to vibrations from the FTIR result. The polymer analysis using Fourier Transform Infrared (FTIR) spectroscopy revealed a diverse range of polymer types across different sites. Common polymers such as Polypropylene (PP), Polyethylene (PE), Polyvinyl Chloride (PVC), and Polyester were identified, with each site exhibiting a combination of polymers. The polymers in this study were also similar to the study of Yonkos et al. in the freshwater Lake Naivasha, Kenya with very low concentrations of 1.5–5 MPs/m^3 [22]. For rivers in contrast, many studies investigating the water phase report concentrations of 0.29 to 340,000 MPs/m^3 [23,24]. Compared to rivers worldwide, the findings in the River Benue are similar. This result is similar to the report of Li et al. [7]. Presence of microplastics in freshwater ecosystems despite of the wealth of data on marine microplastics, to date, only a handful of studies investigate microplastics in a freshwater context. Microplastics have been detected in the surface waters of the Laurentian Great Lakes [25]. The presence of microplastic polymers in surface water were abundant as observed from the intensities of the FTIR spectra. In the screening, polymer isolated from the FTIR spectra of both surface water samples were polyethylene, polypropylene, polyethylene terephthalate, polyvinyl chloride, polyamide, polybutene, polymethylmethacrylate, cellophane, polyurethane and ethylene//ethylacrylate which is similar to the finding of [7]. All the samples contain microplastics, but the number of microplastics differs in different sampling sites. The lowest value of microplastic content accounting for 3.94 ±0.44 was recorded in the New Bridge Site while the higher value of microplastics content accounting for 13.14+0.28 was found in Brewery Site. The difference maybe as a result of some factors including human activities (such as waste disposal, laundry, effluent discharge and fishing activities etc) sampling location and method, sample volume, surrounding environment, weather conditions, affect the amount of microplastics in the environment [26].

Conclusion

The assessment of microplastic contamination in water from River Benue shows the growing environmental challenge posed by plastic pollution. This study has revealed significant levels of microplastics in surface water. Microplastic concentration in surface water was found to be high at the Brewery sampling sites and low at the new bridge site while in sediment samples the concentration of microplastic was highest at Wadata market and least at New Bridge. The spatial distribution of microplastics across different sections of the river suggests that areas with higher population densities (Wadata market site) and industrial activities (Brewery site) exhibit elevated levels of contamination. Regulatory agencies should monitor River Benue and environs to ensure proper waste disposal and management.

References

1. Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, et al. (2015) The IPBES Conceptual Framework-Connecting Nature and People. Current Opinion in Environmental Sustainability 14: 01-16.
2. Borgwardt F, Robinson L, Trauner D, Teixeira H, Nogueira AJ, et al. (2019) Exploring Variability in Environmental Impact Risk from Human Activities across Aquatic Ecosystems. Science of the Total Environment 652: 1396-1408.
3. Costanza R, De Groot R, Sutton P, Van Der Ploeg S, Anderson SJ, et al. (2014) Changes in the Global Value of Ecosystem Services. Global Environmental Change 26: 152-158.
4. Gozlan RE, Karimov BK, Zadereev E, Kuznetsova D, Brucet S (2019) Status, Trends, and Future Dynamics of Freshwater Ecosystems in Europe and Central Asia. Inland Waters 9: 78-94.
5. Wantzen KM, Ballouche A, Longuet I, Bao I, Bocoum H, et al. (2016) River Culture: An eco-social approach to mitigate the biological and cultural diversity crisis in riverscapes. Ecohydrology and Hydrobiology 16: 07-18.
6. Eerkes Medrano D, Thompson RC, Aldridge DC (2015) Microplastics in Freshwater Systems: A review of the Emerging Threats, Identification of Knowledge Gaps and Prioritisation of Research Needs. Water Research 75: 63-82.
7. Li J, Liu H, Chen JP (2018) Microplastics in freshwater Systems: A Review on Occurrence, Environmental Effects, and Methods for Microplastics Detection. Water research 137: 362-374.
8. Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, et al. (2004) Lost at sea: where is all the plastic? Science 304: 838-838.
9. Windsor FM, Durance I, Horton AA, Thompson RC, Tyler CR, et al. (2019) A Catchment-scale Perspective of Plastic Pollution. Global Change Biology 25: 1207-1221.
10. Bergmann M, Mützel S, Primpke S, Tekman MB, Trachsel J, et al. (2019) White and wonderful? Microplastics prevail in Snow from the Alps to the Arctic. Science Advances 5.
11. Brahney J, Hallerud M, Heim E, Hahnenberger M, Sukumaran S (2020) Plastic Rain in Protected Areas of the United States. Science 368: 1257-1260.
12. Jamieson AJ, Brooks LSR, Reid WD, Piertney SB, Narayanaswamy BE, et al. (2019) Microplastics and Synthetic Particles ingested by deep-sea Amphipods in six of the deepest Marine Ecosystems on Earth. Royal Society open science 6: 180667.
13. Sedlak D (2017) Three Lessons for the microplastics voyage. Environmental Science and Technology 51: 7747-7748.
14. Borrelle SB, Ringma J, Law KL, Monnahan CC, Lebreton L, et al. (2020) Predicted Growth in Plastic Waste Exceeds Efforts to Mitigate Plastic Pollution. Science 369: 1515-1518.
15. Lau WW, Shiran Y, Bailey RM, Cook E, Stuchtey MR, et al. (2020) Evaluating Scenarios Toward Zero Plastic Pollution. Science 369: 1455-1461.
16. Bank MS, Swarzenski PW, Duarte CM, Rillig M, Koelmans B, et al. (2021) A Global Microplastic Pollution Observation System to aid Policy. Environ Sci Technol 55: 7770-7775
17. Sarch M, Madakan SP, Ladu BL (1997) Investigating Systems of Fisheries Access Along the River Benue in Nigeria. PLA Notes 30: 40-44.
18. Anyam RW, Aja A I, Amali O (2005) Faced Pollution of the River Benue in Makurdi Metropolis, Benue State, Nigeria: Nigeria. J Inter Disp Stud 4: 11-23.
19. Akaahan TJA, Olabanji FM, Azua ET (2015) Studies on Contamination of Surface-waters of River Benue with Trace Elements at Makurdi, Benue State, Nigeria. Journal of Environmental Chemistry and Ecotoxicology 7: 49-55.
20. Masura J, Baker J, Foster G, Arthur C, Herring C (2015) Laboratory Methods for the Analysis of Microplastics in the Marine Environment. Water Air Soil Pollution 228: 01-10.
21. Yiyang Chen, Dishi Wen, Jianchuan Pei, Yufan Fei, Da Ouyang, et al. (2020) Midentification and quantification of

microplastics using Fourier-transform infrared spectroscopy: Current status and future prospects. Current Opinion in Environmental Science and Health 18: 14-19.

22. Yonkos LT, Friedel EA, Perez Reyes AC, Ghosal S, Arthur CD (2014) Microplastics in Four Estuarine Rivers in the Chesapeake Bay, USA. Environmental science and Technology 48: 14195-14202.
23. Waldschläger K, Lechthaler S, Stauch G, Schüttrumpf H (2020) The way of Microplastic through the Environment–Application of the source-pathway-receptor Model. Science of the Total Environment 713: 136584.
24. Lahens L, Strady E, Kieu Le TC, Dris R, Boukerma K, et al. (2018) Macroplastic and Microplastic Contamination Assessment of a Ttropical River (Saigon River, Vietnam) Ttransversed by a Developing Megacity. Environmental Pollution 236: 661-671.
25. Eriksen M, Mason S, Wilson S, Box C, Zellers A, Edwards W, et al. (2013) Microplastic Pollution in the Surface Waters of the Laurentian Great Lakes. Marine Pollution Bulletin 77: 177-182.
26. Obazele EO, Aganmwonyi I, Chukwuka O, Emeribe CN, Omoigberale MO (2023) Assessment of microplastics in water, sediment, and fish of Ikpoba Rivers of Edo State, Nigeria. African Scientist Journal 24: 366-375.